The Intersection of BIM and Sustainable Design

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During the last few years, we have witnessed the rapid and parallel development of two overarching paradigms in the building design and construction industry: Building Information Modeling (BIM) and Sustainable Design. BIM has risen to prominence out of a desire to streamline the building design and documentation process, to simplify construction management, and to provide the owner with inherently better capabilities for ongoing facilities management during building occupancy. The initial benefits of BIM were seen through the lens of economics: by making building design, construction, and maintenance more efficient, we can ultimately deliver a better project value at a lower construction cost. On the other hand, Sustainable Design has emerged out of global concern for the state of our natural environment. As we add more buildings to our collective built landscapes, sustainable thinking is needed to meet the future challenges of land use, energy consumption, and availability of material resources for building construction. Although BIM and Sustainable Design have emerged from somewhat different underlying market factors, they share a significant common thread: the success of both endeavors depends heavily on a front loaded, deeply integrated building design philosophy that aims to include all team players from the very beginning of a project.

We are already seeing how the design process is heavily affected by BIM implementation on any given project: major design decisions are crucial at the *beginning* phases of the project timeline. The closer the project gets to the end of its design schedule, the more difficult and costly it becomes to incorporate design evolutions. The emphasis here is placed on the schematic design phase of the project. Traditional project design delivery allows for the early conceptual phases to be "fully tested" during design development, and even during final coordination of the construction document deliverables. However, when significant problems and conflicts are identified very late in the documentation process, the time and cost to correct these design deficiencies has typically led to many other problems, including shortened schedules, design revision "bottlenecks", and construction document sets with poor or mediocre design coordination. These design issues then cascade into the construction phase of the project, where "Request For Information" (RFIs) attempt to reconcile the lack of design team coordination. The implementation of BIM helps eliminate problems associated with the traditional project design delivery concept (*Figure 1*).

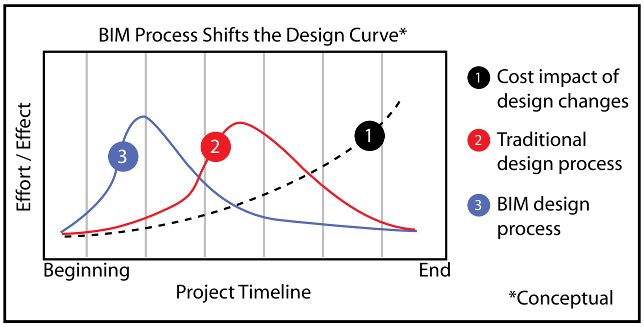

Figure 1: BIM Shift. Courtesy of Construction Users Roundtable, ***www.curt.org***.

Sustainable Design offers very similar benefits to the design process. The most energy-efficient and environmentally conscious designs are typically those that propose passive design concepts from the very beginning. Energy-efficient mechanical, electrical, and plumbing systems can be designed to help heat, cool, ventilate, and power many different types of buildings. However, if the architectural size, form, shape, orientation, and exposure are conceived to perform in harmony with the natural elements, requirements for heating, cooling, ventilation, and electrical loads can be reduced substantially before supplementary engineered systems even begin to take shape. And since the architectural form is typically the main driving force behind a chosen construction system, the building structure plays a crucial role in defining the conceptual starting point for a "deep-green" building design.

But how do we go about integrating the concepts of BIM and Sustainable Design into any given project? Generally speaking, the building design test period must occur mostly during the project's schematic design phase. This design testing phase allows for preliminary verification of the "broad stroke" or "big picture" sustainable design goals. With architectural computer software design tools and modeling programs, the design team can quickly generate multiple design options during the schematic phase that take into account site specific characteristics such as solar orientation and sky path (*Figure 2*). Project specific sites also see winds that often come from a predominant direction. A wind rose (*Figure 3*) is a useful statistical tool for plotting and evaluating average and peak wind speeds and directions. And the interaction of sun and wind effects, in combination with local topographical conditions, can ultimately affect the site specific microclimate. BIM software applications are now taking this a step further by adding utilities and analysis options that integrate with the physical model to provide solid and reliable environmental analysis results. In turn, these results can be used to help shape building design, identify design deficiencies, and prove initial schematic design concepts. Sustainable design strategies such as using thermal mass, natural ventilation, and day lighting can all be evaluated from the viewpoint of the architectural enclosure and structural system. And all of this work can, and should, be done before the project begins heading down the path of detailed project design and documentation. By the time the project reaches the construction pricing and bidding stages, it becomes far more difficult to apply value engineering strategies when sustainability is successfully deeply integrated into the building design.

But what does all of this mean for the practicing structural engineer? It is important for the structural engineer to understand that BIM is not simply a piece of 3-D software. BIM includes database features that can provide valuable feedback and insight, helping the design team make good decisions early in the project. BIM stores information about the entire building in an integrated parametric database. This creates opportunities to use the modeling information for many aspects of the design process. For example, the mechanical engineer can use the early BIM models from the architect to perform computer fluid dynamic (CFD) models to look at ways to naturally ventilate and/or minimize energy use. The structural engineer can import the BIM model into analysis and design software for initial design studies. If the design team can leverage the use of a BIM model

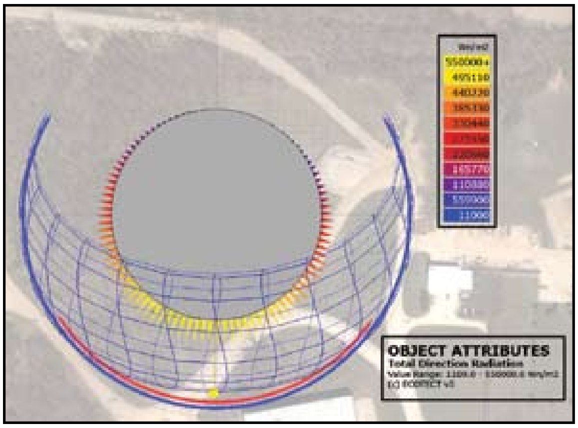

*Figure 2: Sun Path. Courtesy of HOK, **www.hok.com**.*

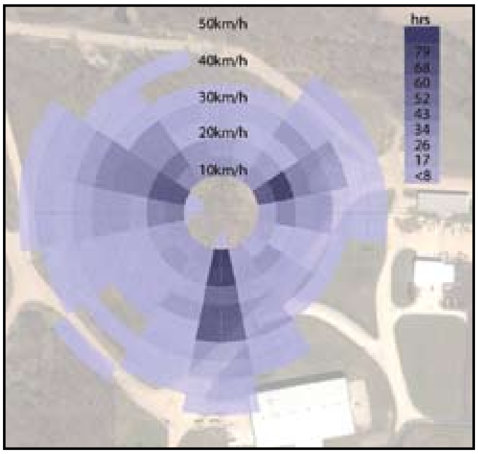

*Figure 3: Wind Rose. Courtesy of HOK, **www.hok.com**.*

in the early stages of design, they can spend their efforts on performing parametric studies or sensitivity analyses rather than spending time re-creating another model's geometry for input into their program. The interoperability of BIM with the many engineering design programs available today is still in the early stages of development. It will continue to be one of the challenges that govern the speed at which the design team can leverage the most out of the BIM process.

The structural engineer can be instrumental in using BIM as a vital tool to deepen a project's sustainable design characteristics. The database features found in BIM can develop structural quantities for the various materials associated with the structural system selected. During the early stages of design, when the structural engineer is typically studying various framing systems, another dimension can be added to the decision matrix: sustainable parameters. Structural systems' materials can be evaluated based on sustainable parameters, in addition to the traditional criteria used by engineers. By allowing the engineer to filter out contents and quantities for a certain material type, the BIM database provides a powerful tool to "test" various systems, such as evaluating and assessing impacts on the projects' overall carbon footprint. For example, the design of a cast-in-place post-tensioned multi-story parking garage creates a potentially high carbon footprint with the use of Portland-cement-only based concrete mix designs. From a sustainability point of view, the use of recycled materials in the concrete mix design encourages the partial replacement of Portland cement with supplementary cementitious materials (SCM's) such as fly ash and slag. However, from a contractor's point of view, a high SCM concrete mix may sometimes be undesirable for flatwork, such as post-tensioned decks.

The BIM modeling database could allow the engineer to define several types of concrete mixes with varying percentages of SCM's. When computing the overall percentages of recycled content in the overall structure, material concrete types and their respective quantities can be broken down by foundations, walls, columns, and flatwork. This information can be retrieved very easily from the BIM model to help support documentation efforts required by sustainable design standards, such as the Leadership in Energy and Environmental Design (LEED) green building rating system.

Every project is unique and should have its sustainability goals defined at the beginning. The engineer will then be able to configure the BIM model to provide the data needed to make the best project-specific decision. By creating the building virtually before it's created physically, the design team can investigate sustainable opportunities for the project such as reducing material waste, increasing recycled content, minimizing embodied energies, and shaping and site placing the structure to maximize energy performance. This is in addition to the more mainstream BIM benefits such as increasing communication and integration, adding the ability to quantify and test variables, reducing errors, omissions, conflicts between disciplines and trades, and reducing construction time. Similarly to BIM, the successful implementation of Sustainable Design on any given project will depend on how well this front loaded process is executed. Not only does this represent a change in design process, but more importantly, it represents a change in design *mindset*. Both BIM and Sustainable Design require a different way of thinking about the entire building design process. Both paradigms call for the entire design team to have a much better understanding of how the building is actually constructed, and how it actually behaves, under any given condition of stress. It is in this way that the design team can truly begin proposing "deep green" designs that minimize both energy and material consumption, serving the interests of both BIM and Sustainable Design.▪

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